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Two Phase Fuzzy Multicriteria Model to Evaluate Teaching

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Two phase fuzzy multicriteria model in evaluating the quality of teaching is presented. The model based upon fuzzy sets and approximate reasoning to determine the ranking of the quality of teaching taught in several courses. The first phase uses the similarity function to dampen the fluctuation of extreme values of data. The second phase based on fuzzy synthetic and multicriteria decision to reduce sub-criteria calculation and offered the best choice in making decision. The used of the model increases the accuracy of the results made in evaluating situation that involves subjectivity, vagueness and imprecise information. Numerical examples produced are comparable to results given by other fuzzy evaluation approaches.

Keywords: *Evaluation, Fuzzy sets, Standard fuzzy sets, Similarity function, Fuzzy synthetic decision matrix, decision matrix, Decision criteria, Fuzzy satisfaction function.*

Introduction

Evaluation is an essential process in decision-making environments. Most evaluation techniques involve handling cases like subjectivity, fuzziness and imprecise information. Application of fuzzy sets theory in evaluation systems can improve the evaluation results (Turban, et al., 2000). Several researchers have tried to solve this problem, for example in personnel selection through analytical hierarchy process (AHP), (Saaty, 1995; Sonja, 2001).

Several researches have been focus on a combination of fuzzy logic model with multi objective decision that can assist in reducing errors in making a judgment (Liang & Wang, 1992; Pedrycz & Gomide, 1998). These researches provide approaches of judgment procedure on personnel selection through development of AHP fuzzy multi criteria. It is cited as being able to minimize the subjectivity. Several researches in fuzzy evaluation methods have been discussed in (Laarhoven & Pedrycz, 1983; Li & Iiacqua, 1994; Turksen, 1992; Yamasita, 1997; Biswas, 1995; Chu, 1990). An algorithm is proposed based on fuzzy similarity function, fuzzy synthetic decision and ranking procedure through satisfaction function.

In this paper, a new Two Phase Fuzzy Multicriteria Model is proposed enhancing the methods introduced by Chu (1990) and Biswas (1995). These methods are the fuzzy evaluation of student answer scripts and evaluation of university teaching quality with fuzzy sets and approximate reasoning. In evaluating student answer scripts, Biswas introduced fuzzy set mark and standard fuzzy set for grading. Fuzzy set marks that are given by the examiner are compared to the standard fuzzy set grade using the similarity function. Grades are given to the question based on the most similar (the highest similarity value calculated) grade with the fuzzy set mark. From the grade allocated, the midpoint mark is matched and total mark is computed by aggregating the multiplication of mark and weight of each question respectively. On the other hand, Chu (1990) evaluated teaching quality by obtaining fuzzy synthetic decision matrix by operation of vector dot product between normalized original data and the weight. Next, the decision matrix is computed through the process using decision criteria set and fuzzy approximate reasoning. Lastly, the ranking is identified by calculating the satisfaction function based on the decision matrix.

The basic notation about fuzzy sets in evaluating quality performance is introduced in section 1. The model proposed and its algorithm are based on fuzzy multi phase evaluation system presented in section 3 and 4. The experimental results and conclusion are given in section 5 and 6.

Basic Notation

A fuzzy sets from a score of grade given by 35 students are generated to evaluate teaching qualities delivered by the lecturer in one class. The generated fuzzy sets characterize the membership values $\mu_A(x)$ taken from the range [0, 1] and as in Definition 1.

Definition 1 Fuzzy Set

Let A, a fuzzy set in the universe of discourse X. The fuzzy set A is defined

$$A = \{(\mu_A(x), x) : x \in X\} \tag{1}$$

where $\mu_A : X \rightarrow [0,1]$ mapping of fuzzy membership function for fuzzy set A and $\mu_A(x)$ describe a degree of membership of $x \in X$ in fuzzy set A. Equation (1) can be written as $A = \{\mu_A(x)/x : x \in X\}$.

The membership value $\mu_A(x)$ expresses the degree to which element x (individual achievement) belongs to fuzzy set A (Grade A or range of evaluation mark) defined as A = { (x, μ(x)) / x $\in$ U}. The fuzzy sets representing the teaching quality according to the criteria and standard fuzzy sets for grade A, B, C, D, and E are determined using human judgment [1, 3]. The grade for each criterion of five courses is accorded by solving the fuzzy similarity function (2).

$$S(F, M) = \frac{\hat{F}.\hat{M}}{\max(\hat{F}.\hat{F}, \hat{M}.\hat{M})}, \tag{2}$$

where $\hat{F} = (\mu_F(x_1), (\mu_F(x_2), \ldots), \hat{M} = (\mu_M(x_1), (\mu_M(x_2), \ldots)$ are the vectors and $\hat{M}$ denotes the transpose vectors A^T, B^T C^T, D^T and E^T. $\hat{F}$ represents transpose vector of fuzzy set f_{ij} where i = 1, 2, 3, 4, 5, 6 and j = 1, 2 3, 4. Set X = (x, x, …,x_n) represents the set of universe of discourse and '•' is the dot product. After the entire grades have been identified, the method maps the grade into class range of marks. The mid-point is then calculated and the method maps the grade of the criteria to the appropriate mid-point mark. The notion of mid-point is introduced to obtain the range for grades A, B, C, D, and E (Turksen & Wilson, 1994). The range and mid-point for the grade is illustrated in Table 1.0 below:

Table 1.0 Mid-point for Range Mark

Grade	Range	Mid-point
A	90 – 100	95
B	70 – 90	80
C	50 – 70	60
D	30 – 50	40
E	0 - 30	15

The midpoint shown in Table 1.0 is obtained by the formula: midpoint $= \frac{X_i + X_{i+1}}{2}$, where X_i and X_{i+1} are the extreme marks of each range. The midpoint marks calculated from the range grade A, B, C, and E are 95, 80, 60, 40 and 15 respectively.

The standard fuzzy sets of the model is identified as follows. Given X is a set universe of discourse, where X $\in$ Grade and grade = {A, B, C, D, E} therefore, the expression X is quantified by defining set X as midpoints of grade. The study uses five grades A, B, C, D and E. The midpoints are selected for range of grade to represent the set universe of discourse X, set X = {95, 80, 60, 40, 15}. The standard fuzzy set indicating the linguistic variable grade of achievement is defined as shown in Table 2.0 (Biswas, 1995). Several approaches to represent linguistic value which use varieties of values are discussed in (Turksen & Wilson, 1994; Biswas, 1995). In this study five linguistic values are used representing the five types of grades A, B, C, D and E to evaluate lecturer's teaching quality (Chu, 1990). Table 2 shows the membership sets of grade representing linguistic variable of achievement scores.

Table 2: Fuzzy Set of Grade

Grade	Linguistic variable	Fuzzy set
A	Excellent	{1.0/95, 1.0/80, 0.9/60, 0.8/40, 0.0/15}
B	Very Good	{0.8/95, 0.9/80, 0.9/60, 0.8/40, 0.0/15}
C	Good	{0.2/95, 0.4/80, 0.9/60, 0.8/40, 0.1/15}
D	Satisfactory	{0.0/95, 0.2/80, 0.4/60, 0.9/40, 0.4/15}
E	Unsatisfactory	{0.0/95, 0.0/80, 0.2/60, 0.4/40, 1.0/15}

The model operation process uses fuzzy similarity function previously defined in equation (1). The grade is accorded to each criterion based on the maximum similarity value (Biswas, 1995; Turksen, 1992).

The fuzzy total mark is calculated by aggregation multiplication of criteria score mark with appropriate weight shown in (3)

$$\textbf{Total mark} = \frac{1}{N} \sum [W_i \times F_i)] \tag{3}$$

where $N = i \times 100$ and i = 1, 2, 3, ...,6. Weights for factors F_1, F_4 and F_6 are W_1 = {0.35 0.30 0.25 0.10} W_4 = {0.35 0.40 0.15 0.10} and W_6 = {0.50 0.40 0.10} respectively. Weights W_1, W_4, W_6 consist of four and five entry elements for the weight vector because there are same size number of criteria under factor categories F_1, F_4 and F_6 (4, 4, 3 criteria). For vector factors F_2, F_3, and F_5 there is only one criterion so the weights W_2, W_3, and W_5 are equal to one.

The fuzzy midpoint mark obtained is used as input to develop a fuzzy synthetic matrix R where each entries r_{ij}, i = 1, 2, 3, ...5 represent number of courses and j = 1, 2, 3, ...6 represent six factors. After the r_{ij} entries have been computed, it is named matrix R which is considered as an input to obtain fuzzy matrix C using combination of multi criteria as follows:

The decision criteria C_i (for i = 1, 2, 3, ..., 7) is the intersection or combination of factor rules which in form of antecedent of the rule. The precedent of the rule indicates the conclusion in term of linguistic variable A_k (k = 1, 2, ..., 5). The combination multi criteria rules are described in Table 3 can be generalized as in equation (4)

$$\text{If } (C_i = \bigcap_{j=1}^{6} \bigcup F_j) \text{ then } A_k \tag{4}$$

C_i = the decision criteria for seven
F_j = Factor rules (j = 1, 2, 3, 4, 5, 6)
A_k = linguistic variables
k = grade

Table 3: Combination Multi Criteria Rules

Decision Criteria	Factor rule	Linguistic variable	Description	Appraisal set
C_1	$F_1 \cap F_4$	A_1	Satisfactory	v
C_2	$F_1 \cap F_5$	A_1	Satisfactory	v
C_3	$F_1 \cap F_4 \cap F_6$	A_2	Very satisfactory	$v^{3/2}$
C_4	$F_1 \cap F_4 \cap F_6 \cap (F_2 F_3)$	A_3	Very very satisfactory	v^2
C_5	$F_1 \cap F_4 \cap F_5 \cap F_6$	A_3	Very very satisfactory	v^2
C_6	$F_1 \cap F_4 \cap F_5 \cap F_6 \cap (F_2 \cup F_3)$	A_4	Perfect	$\begin{cases} 1, & v = 1 \\ 0, & v \neq 1 \end{cases}$
C_7	$\tilde{F}_1 \cap (\tilde{F}_4 \cap H_2 \tilde{F}_6)$	A_5	unsatisfactory	

For example, the decision criteria C_1 rule can be written as

$$\text{If } C_1 = F_1 \cap F_4 \text{ then } A_1 \text{ satisfactory } A_1(v) = v.$$

The linguistic variables A_j (j = 1, 2, ...5) description is given in the fourth column in Table 3 as satisfactory, very satisfactory, very very satisfactory, perfect and unsatisfactory respectively. The appraisal set is defined as A = $\{A_k\}$, k = 1, 2, ..., K, K = 5, where $v \in V$, V = $\{v_l\}$ = {0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1} and l = 1, 2, ..., L, L = 11. To decrease the weight factor, fuzzy concentration method is used [16]. For example the factor rules for the decision criteria C_7, in Table 3 contain the complement variable of F_6 denoted by $\tilde{F}_6$ which is characterized linguistically as very bad. The H_2 notation shown in equation (5) is the mood concentrator indicate the linguistic value 'very' (Klir, 1998).

$$H_2\tilde{F}_6 = \underline{\underline{\Delta}}(\tilde{F}_6) \tag{5}$$

The fuzzy matrix C expresses as C = { c_{ij} } for i = 1, 2, 3, 5 and j = 1, 2, 3,...7. is used to obtained the fuzzy decision matrix D defined in equation (3). Matrix D is developed through the formation of fuzzy matrix $D_j = (d_j(m, l)) \in M_{m \times l}$, i = 1, 2, 3,...7, The entries matrix D_j are computed using matrix C = (c_{ij}) by fuzzy reasoning as

$$\text{if } x = \tilde{c}_i \text{ then } A_{r_i}$$

where i = 1, 2, 3, 4, 5, 6, 7 and r = 1, 1, 3, 3, 4, and 5. The element of matrix D_j is obtained as $d_j(m, l) = 1 \wedge (1 - c(\tilde{u}_m) + \text{Ak}(v_l))$, where v_l = {0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1}, m = 1, 2, 3, ... 5, and = 1, 2, ..., 11. Therefore, the multicriteria decision matrix D is calculated from the resulting matrix D*j* following the formula given in equation (6).

$$\mathrm{D}= \bigcap_{\bullet} D_j \underline{\Delta}(\prod_{j=1}^{7} d_j(m,l) \tag{6}$$

Achievement score can be ranked using the satisfaction value *S(m)* in equation (7)

$$S(m) = \frac{1}{\alpha_{maks}} \sum_{l=1}^{11} H_l(E_{m\alpha}) \Delta\alpha_l \tag{7}$$

where α = degree of membership decision matrix D, $\alpha_l \Delta = \alpha_l - \alpha_{l-1}, = \alpha_0 = 0$, HI ($E_{m\alpha}$) = midpoint of V_l (l = 1, 2, 3...,11), and α_{max} = maximum degree of membership row matrix in D.

Proposed Model

The basic of the proposed model is the integration of the fuzzy set and the fuzzy approximate reasoning discussed in (Chu, 1990). The proposed model are expected to enhance the evaluation process under uncertainties environment. The model involves the computation of the fuzzy total marks for five courses U_1, U_2, U_3, U_4, and U_5 by assigning midpoints mark of grade obtained from the fuzzy similarity function (Biswas, 1995). The proposed model transforms the original frequencies of score grade into a fuzzy set A in the universe of discourse X. The membership value $m_A(x)$ maps every element of the universe of discourse *X* to the interval of [0, 1]. In this study the set of universe is defined as in definition 2.

Definition 2 Set of Universe of Discourse *X*

The set of universe of discourse *X* is the range fuzzy mark given by *X* = {95, 80, 60, 40, 15} (refer table 1) represented by the midpoint marks. The range indicate fuzzy marks grade A, B, C, D and E.

Definition 3 Degree of Membership

Degree of membership $\mu_A(x)$ is defined as the degree of the belonging fuzzy set score grade to the universe of discourse *X* for each criteria, as

$$f_{ij} = \{\mu_{f_{ij}}(x)/x, x \in X\}$$

Transforming fuzzy Sets Grade

The matrix T_i size $m \times n$, where m, n are the row and column respectively and i = 1, 2, 3, 4, 5, 6. The matrix generalized as $T_i = [e_{ij}]$, where e_{ij} is the entry of the matrix representing the value of frequency score grade. The matrix T_1 consists of four rows and five columns since there are four criteria within factor 1 assigned with the and each is allocated normalized frequency value of score on five grades A, B, C, D, and E. Similarly T_2 is matrix 1×5, T_3 is matrix 1×5, T_4 is matrix 4×5, T_5 is matrix 15, and T_3 is matrix 3×5. These matrices consist of five columns representing five grades and different number of rows for different categories of factors for T_2, T_3, T_4, T_5, T_6 which are 1, 1, 4, 1, and 3 respectively. Therefore the study takes all elements in matrices T_i, i = 1, 2, 3, 4, 5, 6 represent the score for grade A, B, C, D, and E; therefore, it is appropriate for all rows to be taken as a fuzzy membership sets for $f_{11}, f_{12}, f_{13}, f_{14}, f_{21}, f_{31}, f_{41}, f_{42}, f_{43}, f_{44}, f_{51}, f_{61}, f_{62}$, and f_{63}.

Table 4: Defining Fuzzy Set

Criteria	Fuzzy set				
f_{11}	{0.0571/95	0.4000/80	0.3429/60	0.2000/40	0.0000/15}
f_{12}	{0.4000/95	0.3140/80	0.2286/60	0.0286/40	0.0286/15}
f_{13}	{0.3143/95	0.4571/80	0.1143/60	0.0571/40	0.0571/15}
f_{14}	{0.3714/95	0.1429/80	0.2000/60	0.2286/40	0.0571/15}
f_{21}	{0.3143/95	0.4857/80	0.1429/60	0.0571/40	0.0000/15}
f_{31}	{0.2000/95	0.3714/80	0.4000/60	0.0286/40	0.0000/15}
f_{41}	{0.0571/95	0.4000/80	0.2571/60	0.2286/40	0.0571/15}
f_{42}	{0.1714/95	0.4286/80	0.2286/60	0.1714/40	0.0000/15}
f_{43}	{0.4000/95	0.2571/80	0.2000/60	0.0571/40	0.0857/15}
f_{44}	{0.3429/95	0.2857/80	0.1714/60	0.1429/40	0.0571/15}
f_{51}	{0.2000/95	0.3714/80	0.1714/60	0.0286/40	0.0000/15}
f_{61}	{0.4857/95	0.3143/80	0.1714/60	0.0286/40	0.0000/15}
f_{62}	{0.0571/95	0.5143/80	0.2000/60	0.1429/40	0.0857/15}
f_{63}	{0.0286/95	0.6000/80	0.2286/60	0.1429/40	0.0000/15}

For example the fuzzy set f_{11} = {0.0571/95, 0.4000/80, 0.3429/60, 0.2000/40, 0.0000/15} in Table 4 can be translated as the degree score given by respondents to teaching quality classified under F_1 that is 5% for mark 95 (grade A), 40% mark 80 (grade B), 34% mark 60 (grade C), 20% mark 40 (grade D) and 0% mark 15 (grade E). The same way applies to the rest of fuzzy set factors. These fuzzy sets are used to illustrate the degree achievement score obtained in grade A, B, C, D and E for all the factors. The symbol "/" is used to indicate the relationship between percentage score and the grade. For example the fuzzy set for criteria f_{11} in Table 4 is {0.0571/95, 0.4000/80, 0.3429/60, 0.2000/40 0.0000/15}.

Ranking the Performance

Data set on frequencies score of grade given by 35 students toward teaching quality criteria taken from Chu (1990) is used for experimenting the algorithm The teaching quality criteria f_{ij} is categorized under one factor F_i where i = 1, 2, 3, ..., 6. After the total fuzzy marks are computed and normalized, the midpoint is assigned to each criteria (refer Table 1.0) according to the grade produced by similarity function in equation (3) is again used as an input to create the synthetic decision matrix R. Utilizing the combination multi criteria rules as in Table 3.0, the matrix R is then transformed into the matrix C. Next matrix Dj = ($d_j(m, l) \in M_{mxl}$), where j = 1, 2, 3,...,7, m = 1, 2, ...5, l = 1, 2, ...11 are formed from matrix C = (c_{ij}) by fuzzy reasoning rule as in (Chu, 1990). The matrix decision D is then created through the multiplication of all matched entries $d_j(m, l)$. Lastly from matrix D, the five courses U_i are then ranked according to the calculated satisfaction value. The highest satisfaction value is considered as the best teaching quality which implies that the students are much more satisfied with teaching qualities.

Two Phase Fuzzy Multicriteria Model Algorithm

Step 1 Compute matrix T_i, i = 1, 2, ... 6, where $T_i = [e_{ij}]$, i > 4 and j = 1, 2, 3, 4, 5, i represent the number of criteria and j denoted grade.

Step 2 Develop fuzzy set f_{ij}, i = 1, 2, 3,...6 and j > 1.

Step 3 Construct standard fuzzy set model
- i. Define set universe of discourse X = {95, 80, 60, 40, 15}.
- ii. Define standard fuzzy set for A, B, C, D and E

Step 4 Find the similar fuzzy set grade for fuzzy set criteria f_{ij}, where i = 1, 2, 3, ..., 6 and j = 1 or 3 or 4 using the fuzzy similarity function. Let 2 fuzzy set F and M in set X then the similarity value is computed by:

$$S(F, M) = \frac{\hat{F}.\hat{M}}{\max(\hat{F}.\hat{F}, \hat{M}.\hat{M})}$$

Step 5 Obtain the score grade for criteria which have the maximum similarity value.

Step 6 Assign the midpoint mark to each criterion f_{ij}, where i = 1, 2, 3, ..., 6 and j >1 according to their grade.

Step 7 Compute the fuzzy total mark

$$\text{Total mark} = \frac{1}{N} \sum [W_i \times F_i], \text{ where } N = i \times 100,$$

$i = 1, 2, 3, \ldots, 6.$

Step 8 Find synthetic decision matrix R, R = $\{r_{ij}\}$, i = 1, 2, ...,5, j = 1, 2,...,6. where i, j represent number of courses and factors respectively.

Step 9 Create decision matrix C from matrix R.

Step 10 Develop multi criteria decision matrix D using fuzzy approximate reasoning:

i. Get fuzzy matrix $D_j = (d_j(m, l)) \in M_{m \times l}$ where $i = 1, 2, \ldots 7$. From matrix $C = (c_{ij})$ and fuzzy approximate reasoning.

ii. Compute the multi criteria decision matrix D from matrix D_j (j = 1, 2, ...7) using the following formula:

$$D = \bigcap_{\bullet} D_j \underline{\Delta} (\prod_{j=1}^{7} d_j(m,l))$$

Step 11 Obtain the ranking score by calculating satisfaction value as follows:

$$S(m) = \frac{1}{\alpha_{maks}} \sum_{l=1}^{11} H_l(E_{m\alpha}) \Delta\alpha_l$$

where α = degree of membership of grade $E_{m\alpha}$ matrix D

$\Delta\alpha_l = \alpha_l - \alpha_{l-1}, \alpha_0 = 0$

$H_l(E_{m\alpha})$ = midpoint of $V_l (l = 1, 2, 3 \ldots, 11)$

α_{max} = the maximum degree of membership matrix D

Rank the satisfaction values in ascending order.

Result

The data used in this study is adopted from data evaluation of teaching quality (Chu, 1990). The results of three models; fuzzy evaluation (Biswas, 1995; Chu, 1990) and the proposed model are compared. The ranking is made by arranging the calculated total fuzzy mark and satisfaction value as given in section 2. The satisfaction value (**satisfaction**) and the ranking of the score (**Rank**) obtained from the proposed method of courses (**courses**) are compared with result produced by Chu and Biswas. The percentage of the error (**% error**) percentage of accuracy (**% acc**) of Biswas and the proposed method are computed based on the results given by Chu. The higher value of the satisfaction value implies that the students are satisfied with the teaching quality delivered. From the results the selection of courses based on satisfaction values can be ordered as U_4, U_1, U_3, U_5, and U_2 respectively. The experimental results are presented in Table 5 and Figure 1 show the graphs of the ranking of the methods. The experimental results show that the proposed model gives a comparable error towards the actual values with highest accuracy.

Table 5 Experiments by Biswas, Chu And Model

Method	Chu		Biswas		Proposed	
Courses	Satisfaction	Ranking	Satisfaction	Ranking	Satisfaction	Ranking
U_1	0.8339	2	0.6421	2	0.8994	2
U_2	0.7530	5	0.6371	3	0.8045	5
U_3	0.8258	3	0.5638	1	0.8987	3
U_4	0.8453	1	0.5792	4	0.9015	1
U_5	0.7527	4	0.6550	1	0.8945	4
% error	0		17.74%		8.86%	
% acc				20%		100%

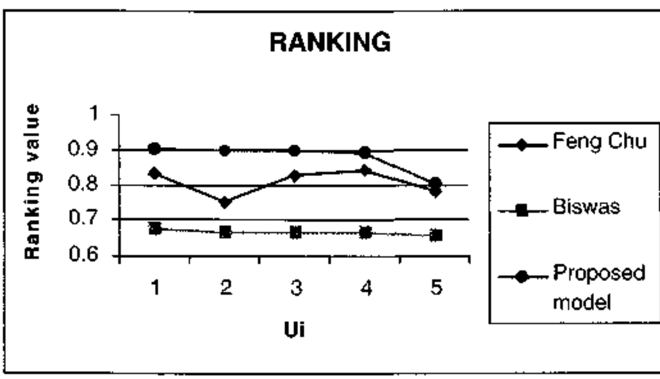

Figure 1: Ranking the Course U_i

From Figure 1, these methods reflect the uncertainty associated with subjective judgment in ranking made by the three models. However, the proposed model shows the highest ranking score among the three methods. The proposed model with the concepts of combining the Biswas and Chu's model, has shown advantages in generalizing the evaluation of the performance achievement. To ensure that the evaluation process can be conducted consistently the set degree of membership f_{ij} represented the linguistic variable are attained and the precise ranking could be done through formulation of similarity function and approximate reasoning of the fuzzy set theory.

Conclusion

A new fuzzy model has been proposed for the evaluation of the teaching quality. The model has been implemented on a computer programmed used C++ language which is suitable for various fuzzy environments. The model could be used as an alternative approach in solving the problems that involve uncertainty. Experimental results produced are comparable to other results obtained from models by Biswas and Chu. The main contribution of the research model was the usage of fuzzy expert system consisting of set of rules in the form of IF (antecedent) THEN (Conclusion). If the combination factors were accurately defined then the evaluation output comes nearer to precision. For the purpose of the study definition of A was taken from Chu's model with several amendments. Thus the accuracy definition of A could further be improved to produce a reliable performance evaluation. To extend this effort we propose a further research to obtain a universal view on an appropriate combination factors and the classification of midpoint which could be improve the performance of the proposed model.

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